Explosion Puffed Dehydrated Potatoes
III. Estimated Cost of Commercial Production
Using Shortened Cycle

A method for preparing quick-cooking dehydrated potato pieces employing superheated steam in the explosive puffing process is described. It is estimated that quick-cooking dice produced in this way could be made for only about 3 cents per pound more than the price of conventionally hot-air-dried dice of the same size. The process has also been successfully used with potato slices. Maine Katahdins were found to respond favorably to the same conditions recommended for Idaho Russets.

CONTENTS

This is a report of work done at the

Eastern Utilization Research and Development Division
Philadelphia, Pa. 19118

EXPLOSION PUFFED DEHYDRATED POTATOES III. ESTIMATED COST OF COMMERCIAL PRODUCTION USING SHORTENED CYCLE

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INTRODUCTION

Explosive puffing, as a means of imparting quick-cooking properties to dehydrated pieces of fruits and vegetables, continues under investigation at the Eastern Utilization Research and Development Division near Philadelphia. The idea was conceived by Cording and Eskew (1)* in 1960. It has been applied to white potatoes (7, 4), carrots (7, 2, 14, 10), beets (2), sweet potatoes (11), apples, and blueberries (8). DellaMonica 1965 (6) showed that explosion puffed dehydrated carrot dice retain more β-carotene when reconstituted than do conventionally dried dice.

The publications cited above (except 14) describe materials prepared with a gun heated externally by gas burners alone. It soon became apparent that if the process were to prove commercially feasible a gun would have to be developed specifically for fruits and vegetables. Such a unit was designed by Heiland (9, 12). It employs injected superheated steam in addition to external gas heating. More than a year's experience with this unit has shown it to be suitable for commercial use. It is now being manufactured by Wilmot Fleming Engineering Co., Hasbrook below Cottman Street, Philadelphia, Pa. 19111. Detailed construction drawings are available.** The use of this gun in proposed commercial production of quick-cooking dehydrated carrot dice has been described (14).

This publication reports details of the new operating procedure employing superheated steam with potatoes and gives an estimate of the cost of commercial operations.

PROCESS

Preparation of Potatoes for Puffing

The flow sheet (fig. 1) depicts the processing steps in the area where they differ from those of the conventional manufacture of dehydrated potato dice. Peeling, washing, trimming, dicing, and washing of the dice are done conventionally, as are electronic sorting, manual inspection, and packaging (13).

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* Underscored numbers in parentheses refer to Literature Cited at the end of this report.

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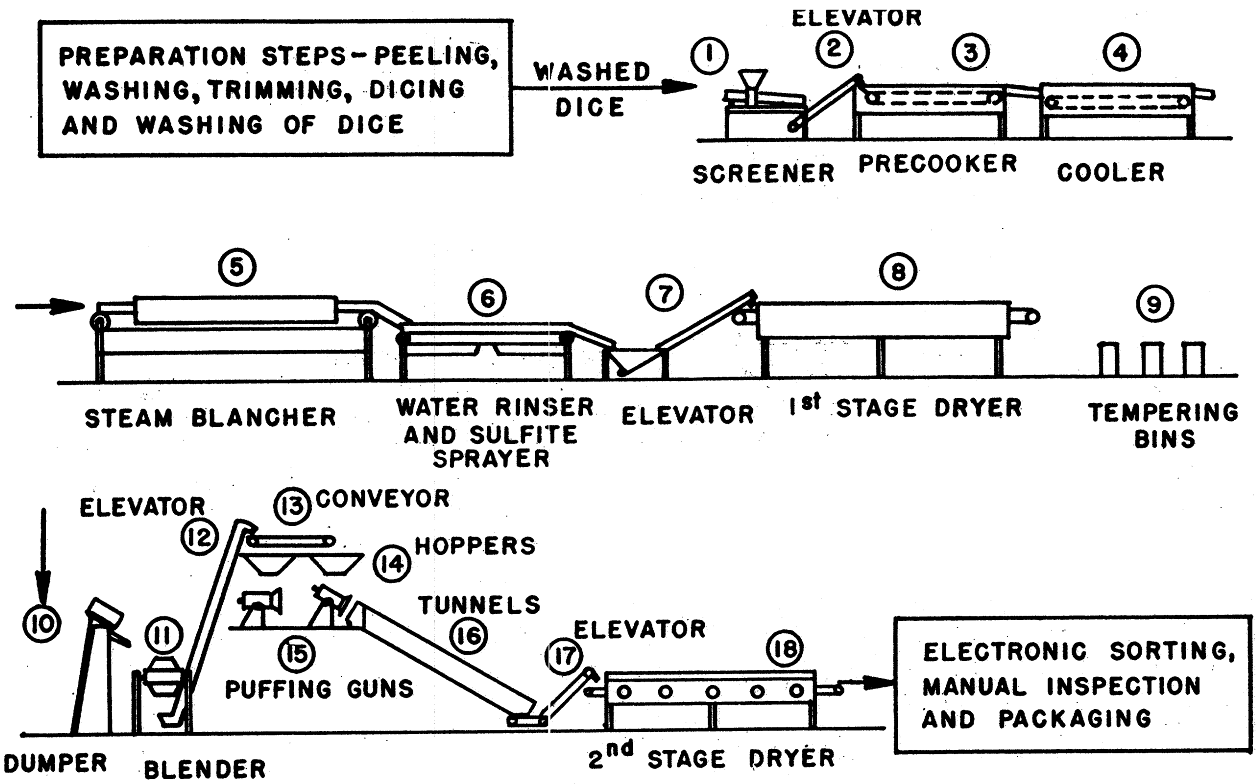

Figure 1. - Flow sheet of process for preparing explosive puffed dehydrated potato dice.

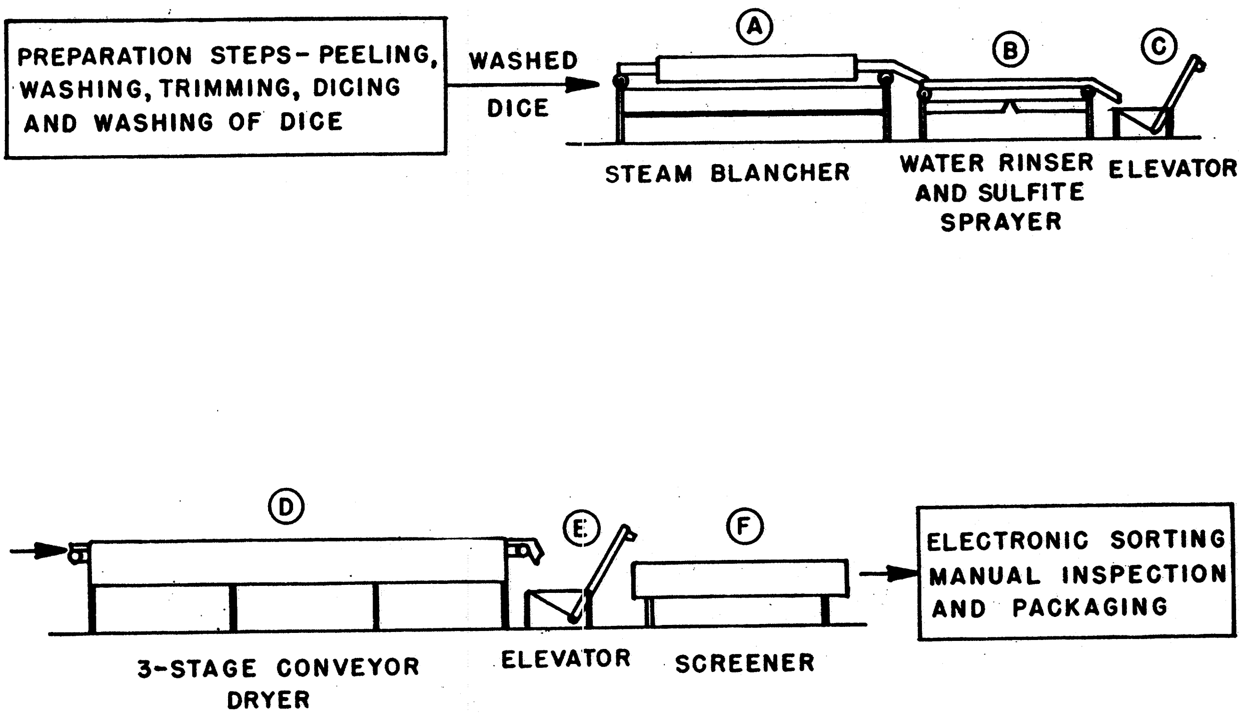

Figure 2. - Flow sheet of process for preparing conventional dehydrated potato dice.

Figure 2 shows the steps in that area of conventional processing where deviations from the process for explosive puffing occur. A comparison of the two figures will be especially helpful when relative costs are being considered.

Since dicing invariably results in the development of some fines that would contribute to nonuniformity of product, the dice (fig. 1) are passed over a vibrating screen (item 1) equipped with slots 2 inches long and 3/16-inch wide. Approximately 12 percent passes through the screen as fines, which may be used in making other potato products such as flakes or patties. The fraction passing over the screen is precooked for about 30 minutes at 160° F. and then cooled for about 10 minutes in water below about 70°. Precooking and cooling have been found to eliminate pastiness in dehydrated mashed potato flakes (3, 5). These steps here serve a similar function, which is important if the reconstituted dice are to be mashed.

Any residual enzyme is inactivated by blanching the dice for 8 minutes in atmospheric steam. In order to obtain the desired amount of sulfite in the finished product (200 to 500 p.p.m.) the blanched dice are water rinsed and sprayed with a solution containing 0.5 percent each of sodium bisulfite and sodium sulfite.

Prior to explosion puffing, the dice must be dried to about 20 to 25 percent moisture on a wet basis. This can be accomplished typically in a through-circulation continuous belt dryer in about 2 hours. An air temperature of 200° F. dry-bulb is employed for the first hour and a temperature of 175° for the remaining time. An air velocity of 200 feet per minute and a bed depth of 3 inches are typical. A belt trough dryer could also be used.

Explosive Puffing

Before puffing it is necessary to equilibrate the partially dried dice to attain uniform moisture distribution within and among the dice. This requires holding the material at room temperature for approximately 16 hours. Although the equilibrated dice may be puffed at this stage, some clumping may occur as a consequence of gelatinization of surface starch caused by steam condensation and heating in the gun. It is, therefore, recommended that the equilibrated dice be coated by tumbling in contact with an anticaking agent such as ultra finely divided hydrated sodium silico aluminate. One such product (Zeolex 7) has been tested and found effective in preventing clumping and sticking in the gun. Before charging to the gun, the dice, predried to a proper moisture content for puffing as already described, are tumbled for about 5 minutes in contact with an amount of the powder equivalent to 0.75 percent of the potato solids in the dice. Some of the powder will be lost in puffing and final drying, but this is inconsequential as it will have already served its purpose. Zeolex 7 is manufactured by J. M. Huber Corp., of Menlo Park, N. J. Zeolex (Sodium Silico Aluminate) is sanctioned by the United States Food and Drug Administration as an anti-caking and conditioning agent in foods up to 2% and by the Meat Inspection Division of the U.S.D.A. up to 2% in dry seasoning and curing mixtures used in meat or meat products. Zeolex is limited to 2% in the final food because it has no nutritional value. Zeolex is exempt from the 1958 Amendment to the Food and Drug Laws and has GRAS (Generally Recognized As Safe) status. The generic name "Sodium Silico Aluminate" is used for label identity.

The relatively slow operating cycles previously suggested for potatoes (4) were the consequence of using external heat only. By injecting superheated steam while maintaining gun wall temperature at the desired point with an external gas flame, the cycle can be greatly shortened. The use of superheated steam, improved heating, and surface coating eliminates the necessity for separating the pieces into two sizes and processing the fractions separately as previously recommended (4).

Figure 3 (top) shows diagrammatically the location of the perforated steam tube within the gun barrel and the position of the thermocouple that shows the temperature of the superheated steam as it actually enters the gun. It (bottom) also shows the location of controls for gun operation; this facilitates an understanding of the following sequential steps to be taken in initiating gun operation.

1. Admit steam to the superheaters (1) by opening valve (2).
2. Turn on electric power to the superheaters and set thermostat (3) (temporarily) to give 500° F. steam.
3. Close gun lid and start rotation.
4. Light gas burners and admit steam to gun through quick-opening valve (4).
5. Adjust gas rate to give a gun surface temperature of 330° to 340° F., as indicated by recorder (5). This is actuated by a sliding thermocouple on the outside of the gun barrel.
6. Adjust steam pressure by means of valve (2) to 60 p.s.i. as indicated by gage (6) on gun shaft.
7. Shut off gas burners and shunt steam to the bypass by closing valve (4).
8. Charge the gun with potato pieces, for example 20 pounds of 3/8-inch dice, and start rotation. Relight gas and maintain gun surface temperature between 330° and 340° F.
9. Open valve (4) admitting steam to the gun.
10. Observe the temperature of superheated steam entering the gun as indicated on recorder (7). Readjust thermostat (3) if necessary to maintain steam at 375° to 380° F. (which corresponds to 67° to 70° superheat) entering the gun. It may be necessary in initiating operations to process several charges until the proper settings of (2) and (3) are achieved. Thereafter, the settings are left the same.

After the foregoing preparations have been carried out, it is possible to process charges in rapid succession as follows: Charge the gun with about 20 pounds of dice, containing between 20 to 25 percent moisture, close the lid, start rotation, light the gas burners keeping the gun surface temperature at 330° to 340° F., and admit steam through valve (4).

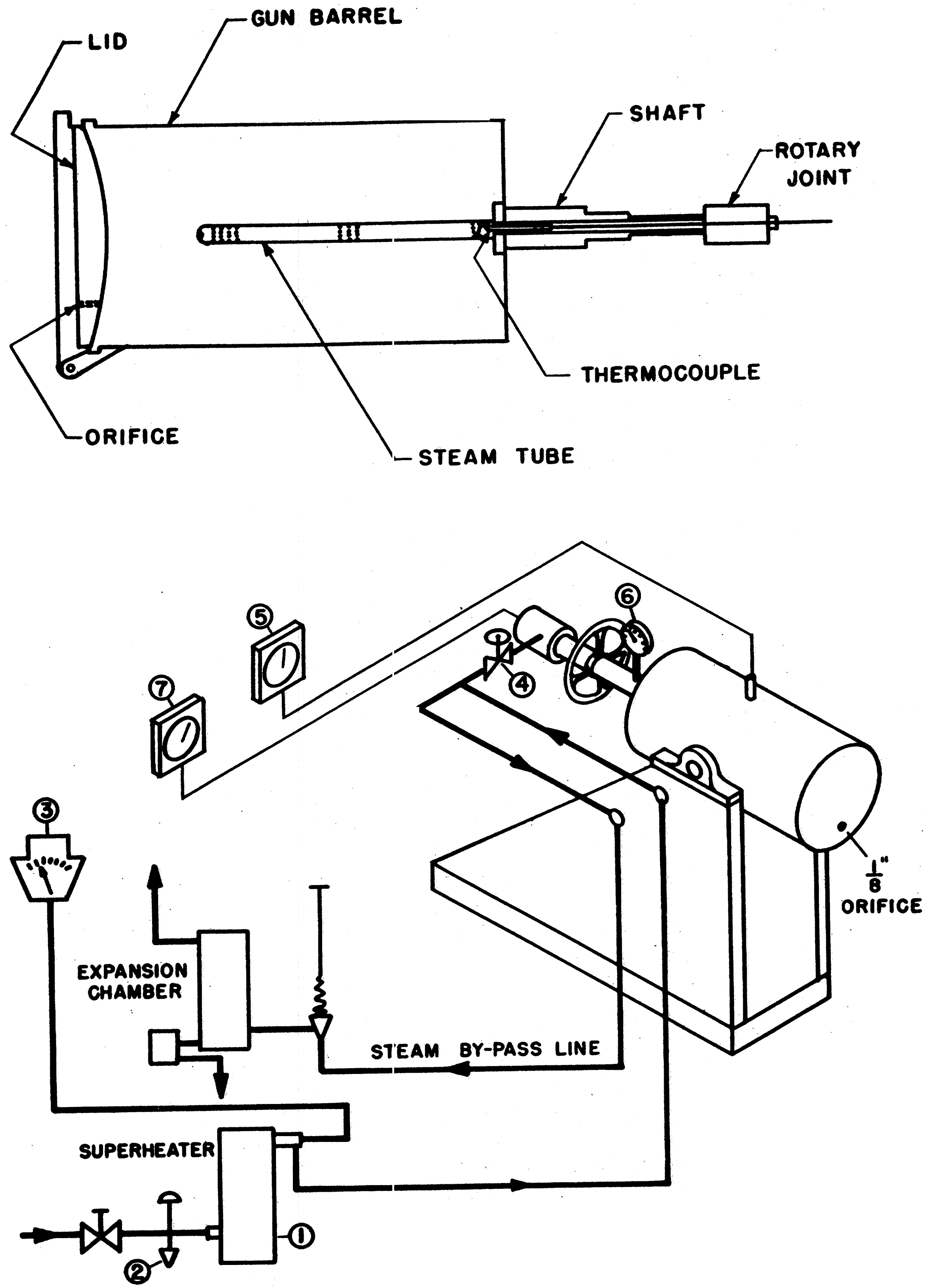

Figure 3. Details of puffing gun (top) and of controls for gun operation (bottom).

When gage (6) reads 60 p.s.i. (in about 1 minute) hold this pressure for an additional 30 seconds, then shut off the gas, tilt the gun, fire it, and shut off the steam. The gun is now ready for reloading and continued operation.

With a properly designed loading hopper it should be possible to charge the gun, fire, and reload in approximately 1-1/2 minutes. This time added to the 1-1/2 minute heating cycle represents 20 charges per hour, theoretically equivalent to approximately 330 pounds per hour of finished product.

It should be noted that the foregoing conditions are employed when a gun with a 1/8-inch vent in the lid is used. A different setting on thermostat (3) will be required if a gun with a 1/4-inch orifice is used.

A small amount of moisture is removed in the puffing process, having been superheated in the gun above its atmospheric boiling point. However, some slight condensation takes place in the gun when the superheated steam contacts the relatively cool charge. Since condensation preponderates, the net result is a slight increase in moisture in the product discharged from the gun. For example, if charged at 22 percent, on discharge the moisture may be 25 percent.

Final Drying

Further drying must be done to put the product in stable form. In a through-circulation belt dryer, a dry-bulb temperature of 150° F. and air velocity of 200 feet per minute will reduce the moisture to between 5 and 6 percent in approximately 1.5 hours. This is with a bed depth of about 3 inches. As in the case of preliminary drying, either a belt trough dryer or a through-circulation continuous belt dryer may be used.

Compression of Puffed Dice

H. I. Sinnamon (10) has reported that the bulk density of explosion puffed carrot dice can be greatly increased by compression after puffing and before final drying. Unfortunately the same effect cannot be obtained with potato dice; they tend to re-expand almost to their original size. When puffed potato dice were passed between rolls set at the clearance of 1/32 inch, bulk density of the dried product increased only by about 8-1/2 percent (from 23.5 to 25.5 pounds per cubic foot). Moreover, unlike carrots, on reconstitution many of the compressed dice contained hard uncooked centers; whereas, the product dried without compression rehydrated uniformly in 5 minutes.

PUFFED SLICES

Dehydrated potato slices are now widely sold for use in casserole dishes. They are generally cut thin from B size potatoes with an Urschel Model OV transverse cutter. This cut is advantageous as it eliminates the loss of some 12 percent fines which characterizes dicing. The product of commerce requires 35 to 45 minutes or more (depending on slice thickness) baking en casserole to become tender (or 20 to 25 minutes boiling to be suited for salad). These periods can be greatly shortened by explosion puffing of the partially dehydrated slices.

The process is substantially the same as that for 3/8-inch dice. The slices are cut about 3/16 inch thick and tray loading during initial drying is approximately 8.8 pounds per square foot for slices as compared with 10-1/2 pounds per square foot for 3/8-inch dice. Moreover, the maximum charge to the gun is 15 pounds instead of 20 pounds. The result is a gun capacity of approximately 250 pounds per hour of finished product as compared with 330 pounds per hour for dice.

The puffed dehydrated slices have a pleasing, plump appearance. They are white and opaque rather than yellowish and translucent. They can be reconstituted for use as boiled potato pieces or for salad, by simmering for 5 or 6 minutes. If they are to be served scalloped or au gratin, the slices should first be simmered 3 or 4 minutes, drained, and then put in the casserole with the other ingredients. Ten minutes baking at 245° F. completes the preparation.

POTATO VARIETIES

In developing this process, practically all the research was done with one variety, Idaho Russets. Also used to a limited extent were Maine Katahdins containing 18 percent solids. The conditions employed were the same for both varieties. The Katahdin dice reconstituted as rapidly as those from the western potatoes and had slightly less tendency to slough.

ESTIMATED COST OF COMMERCIAL PRODUCTION

Since explosive puffing is a new step applicable to the already established process of hot air dehydration, a detailed cost estimate of the entire process is unnecessary. More to the point is an estimate of the additional cost required to produce the new puffed quick-cooking product above the cost entailed in making the conventional dried unpuffed product.

A typical price for unpuffed 3/8- x 3/8- x 3/8-inch pieces is 21 cents per pound, packed in multiwall paper bags of 50 pounds net, in carload lots, F.O.B. processing plant. Assuming typical sales expense and a 12 percent annual net profit on fixed capital investment, the "cost to make" the unpuffed product might reasonably be 15-1/2 cents per pound. The corresponding cost to make quick-cooking puffed potato dice would be about 18-1/2 cents per pound, similarly packed. Cost information beyond that given here may be obtained from the authors.

Basic Assumptions

The plant is assumed to be located in Idaho as an adjunct to a factory already making other potato products. Production would be at the rate of 625 pounds per hour of finished product containing 6 percent moisture. This corresponds (conservatively) to the output of 2 puffing guns, each processing 400 pounds per hour of dice containing 22 percent moisture. The plant would operate 265 days per year, 7 days per week, 24 hours per day (including 2 hours daily clean-up). Sale would be to the remanufacturing trade, the product being packed in multiwall paper bags holding 50 pounds each.

Equipment Requirements

The items listed below are those indicated in figure 1. Where no cost is shown, the cost is considered to be offset by an analogous item used in the conventional process and shown in figure 2.

Item No.	Description	Estimated Cost, dollars
1.	Screener -- with screen having 3/16- x 2-inch slotted holes; to separate fines (about 12 percent of feed). Parts contacting product of stainless steel. Cost corresponds to "F" in figure 2.	
2.	Elevator -- to raise larger size fraction from screener into precooker; throughput 3,010 pounds per hour. Cost corresponds to "C" in figure 2.	
3.	Precooker -- to precook dice for approximately 30 minutes in water at 160° F. Spiral screw within jacketed housing; stainless steel construction. Throughput 3,010 pounds per hour. 1-1/2 hp. motor, variable speed drive.	8,500
4.	Cooler -- to cool dice from precooker to below 100° F., using well water at 70° F. (or lower). Construction similar to item No. 3 but smaller in size.	6,000
5.	Steam blancher -- to heat dice for 6 to 8 minutes in steam at atmospheric pressure. Stainless mesh belt moving through steam box, with variable speed drive. Throughput 2,950 pounds per hour. 1-1/2 hp. motor. Cost corresponds to "A" in figure 2.	
6.	Rinser and sprayer -- to rinse surface starch from dice with water sprays, and then spray dice with solution containing 1/2 percent each of sodium sulfite and sodium bisulfite so as to yield 200 to 500 p.p.m. SO_2 in final product. Stainless mesh belt with drip pans and recirculating pump for sulfite solution. Cost corresponds to "B" in figure 2.	
7.	Elevator -- to lift about 2,920 pounds per hour of dice into feeder of first-stage dryer. Stainless steel construction, 3/4-hp. motor. Cost corresponds to "E" in figure 2.	

8. First-stage dryer -- continuous belt, through-circulation, steam-heated. Overall length about 64 feet; 6-foot feed and discharge ends, 42-foot drying zone. Two 10-foot-wide belts in series, with 10-foot-long section for turning product over and transferring to second belt. Belts of stainless steel. Total horsepower about 100. Total price of first- and second-stage-dryers (items 8 and 18) assumed (conservatively) to be equal to that of 3-stage dryer used in conventional process - "D" in figure 2.

9. Tempering bins -- to store dice from first-stage dryer for 16 hours to equilibrate moisture. Fiberglass reinforced plastic with cover. Size approximately 42 inches high x 48 inches long x 42 inches wide; volume 33.5 cubic feet; holds about 800 pounds of dice. Twenty required. 5,200

10. Dumper -- to elevate bins (9) and dump dice into blender (11). Approximately 15-foot dumping height; lifting capacity about 1,200 pounds. 1-1/2-hp. motor. 2,100

11. Conical blender -- to tumble and mix dice with anticaking powder. Holds dice from one full bin; working volume 33.5 cubic feet. Mixing time about 5 minutes. Five-foot diameter; stainless steel; 5-hp. drive. 4,000

12. Elevator -- to raise to overhead gun platform about 790 pounds per hour of dice from blender, and discharge to conveyor (13). 1-hp. motor. 2,300

13. Conveyor -- to receive dice from elevator (12) and distribute to any two of the three gun feed hoppers. Rubber-belt type with deflectors for discharge. 1/2-hp. motor. 1,400

14. Hoppers -- to feed dice to puffing guns. Three required. Capacity approximately 30 cubic feet each. With chute on outlet to measure volumetrically the charge to the gun. $900 each. 2,700

15. Puffing guns -- three required; two operating and one spare. Equipped for steam injection. Each gun system complete and independent, including gun proper; steam superheating system (electrical); indicator-recorder for gun pressure; indicator-recorder-controller for gun surface temperature (controls gas flame); indicator-recorder for superheated steam temperature. Each system, $12,900. 38,700

16.	Gun discharge tunnels -- to receive dice shot from guns and deliver to conveyor (17). Tunnel about 3 feet in diameter by 25 feet long and inclined 25° above the horizontal. Deflecting, arresting, and collecting pans at bottom of tunnel increase over-all length to about 45 feet. Aluminum and stainless steel construction. $3,600 each.	10,800
17.	Conveyor-elevator -- to collect and combine dice from the two operating tunnels and deliver them to feeder of final dryer (18). Rubber-belt type. 1 hp.	2,800
18.	Second-stage dryer -- same type of construction as first-stage dryer (8). Overall length about 38 feet; 26-foot drying zone; 10-foot-wide stainless steel conveyor belt. Total horsepower about 45. Price of first- and second-stage dryers combined (items 8 and 18) assumed (conservatively) to be equal to that of 3-stage dryer used in conventional process - "D" in figure 2.	
TOTAL ADDITIONAL EQUIPMENT COST FOR EXPLOSION PUFFED DICE		84,500

Additional Capital Investment Required
for Puffing Process

1.	Buildings (1,400 square feet)	15,400
2.	Boilers (600 pounds per hour additional capacity)	2,600
3.	Process equipment (SEE Equipment Requirements.)	84,500
4.	Erection of equipment (18 percent of line 3)	15,200
5.	Instrumentation	800
6.	Piping and ductwork (4 percent of line 3)	3,400
7.	Erection of piping and ductwork (3 percent of line 3)	2,500
8.	Power, installed (60-kw. superheaters, 12-kw. motors)	6,500
9.	Insulation on steam lines	500
10.	Freight on equipment	1,600
11.	Contingencies (10 percent of total)	17,500
12.	Engineering fees (10 percent of total)	17,500
13.	Contractor's fee (4 percent of total)	7,000
	Additional fixed capital (total)	175,000
	Additional working capital	25,000
	TOTAL ADDITIONAL CAPITAL FOR PUFFING PROCESS	200,000

PARTIAL LIST OF EQUIPMENT MANUFACTURERS

The companies listed below supply equipment that can be used in some of the steps in making explosion puffed potato dice. The item numbers refer to the flow sheet fig. 1 and to the Equipment Requirements.

1. Screener

Blaw-Knox Co., Food and Chemical Equipment Division, 1545 Fillmore Ave., Buffalo, N.Y. 14211.

J. H. Day Co., 4932 Beech St., Cincinnati, Ohio 45212.

Simplicity Engineering Co., Durand, Mich. 48429.

2. Elevator

Blaw-Know Co., Food & Chemical Equipment Division (SEE item 1 for address).

Clermont Machine Co., Inc., 280 Wallabout St., Brooklyn, N.Y. 11206.

A. K. Robins and Co., Inc., 713 E. Lombard St., Baltimore, Md. 21202.

3. Precooker

FMC Corporation, Canning Machinery Division, 333 W. Julian St., Box 1120, San Jose, Calif. 95108.

Rietz Manufacturing Co., P.O. Box 847, Santa Rosa, Calif. 95402.

A. K. Robins and Co., Inc. (SEE item 2 for address).

4. Cooler

Same suppliers as for item 3.

5. Steam Blancher

Chisholm-Ryder Co., Inc., Drawer F, Bridge Station, Niagara Falls, N.Y. 14305.

Flodin, Inc., P.O. Box 418, Sunnyside, Wash. 98944.

A.K. Robins and Co., Inc. (SEE item 2 for address).

6. Rinser and Sprayer

Same suppliers as item 5, plus

FMC Corporation, Canning Machinery Division (SEE item 3 for address).

7. Elevator

Same suppliers as item 2.

8. First-Stage Dryer

National Drying Machinery Co., Hancock St. & Lehigh Ave., Philadelphia, Pa. 19133.

Proctor & Schwartz, Inc., 7th St. & Tabor Road, Philadelphia, Pa. 19120.

C. G. Sargent's Sons Corp., Graniteville, Mass. 01829.

9. Tempering Bins

Goodyear Aerospace Corp., Akron, Ohio 44315.

G. B. Lewis Co., 765 Montgomery St., Watertown, Wis. 53094.

Union Steel Products Co., Albion, Mich. 49224.

10. Dumper

Conveyors & Dumpers, Inc., Division of Mercury Industries, Inc., P.O. Box 98, Park Ridge, N.J. 07656.

Essex Conveyors, Inc., 101 Colden St., Newark, N.J. 07103.

Tubar Products, Division of Uhrden, Inc., Sugarcreek, Ohio 44681.

11. Conical Blender

Patterson Division, Patterson Industries, Inc., East Liverpool, Ohio 43920.

The Patterson-Kelley Co., Inc., Process Equipment Division, East Stroudsburg, Pa. 18301.

Paul O. Abbe, Inc., 141 Center Ave., Little Falls, N.J. 07424.

12. Elevator

Same suppliers as item 2.

13. Conveyor

Same suppliers as item 2.

14. Hoppers

Any local fabricator.

15. Puffing Guns

Wilmot Fleming Engineering Co.,*** Hasbrook below Cottman St., Philadelphia, Pa. 19111.

16. Gun Discharge Tunnels

Blueprints for fabrication may be obtained from U. S. Department of Agriculture, Agricultural Research Service, Eastern Utilization Research and Develop-

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*** This is the only company known to have manufactured puffing guns of our design, upon which this publication is based.

ment Division, Engineering and Development Laboratory, 600 East Mermaid Lane, Philadelphia, Pa. 19118.

17. Conveyor-Elevator

Same suppliers as item 2.

18. Second-Stage Dryer

Same suppliers as item 8.

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